Cloud resolving 4DVAR experiment of a local heavy rainfall event using GPS slant delay data

Takuya KAWABATA (*tkawabat@mri-jma.go.jp*), Yoshinori SHOJI, Hiromu SEKO, Kazuo SAITO (Meteorological Research Institute/JMA)

1

NHM-4DVAR is **a cloud-resolving nonhydrostatic 4D-Var data assimilation system** based on the JMA Nonhydrostatic Model (**NHM**), to investigate the mechanism of heavy rainfall events induced by mesoscale convective systems (MCSs).

Model

- Forward model : NHM (full nonhydrostatic model)
- Adjoint, tangent linear model :
  - Dynamic frame work
  - Cloud microphysical process (Warm rain)
  - Lateral boundary conditions

Control variables

Wind (*u*,*v*,*w*), surface pressure, potential temperature, nonhydrostatic pressure, total water, relative rain water, pseudo relative humidity (for lateral boundary)

Observational data

Doppler radial wind, radar reflectivity,
GPS precipitable water vapor (**GPS-PWV**),
GPS slant delay (**GPS-SD**),
surface wind, surface temperature, (wind profiler, RASS)

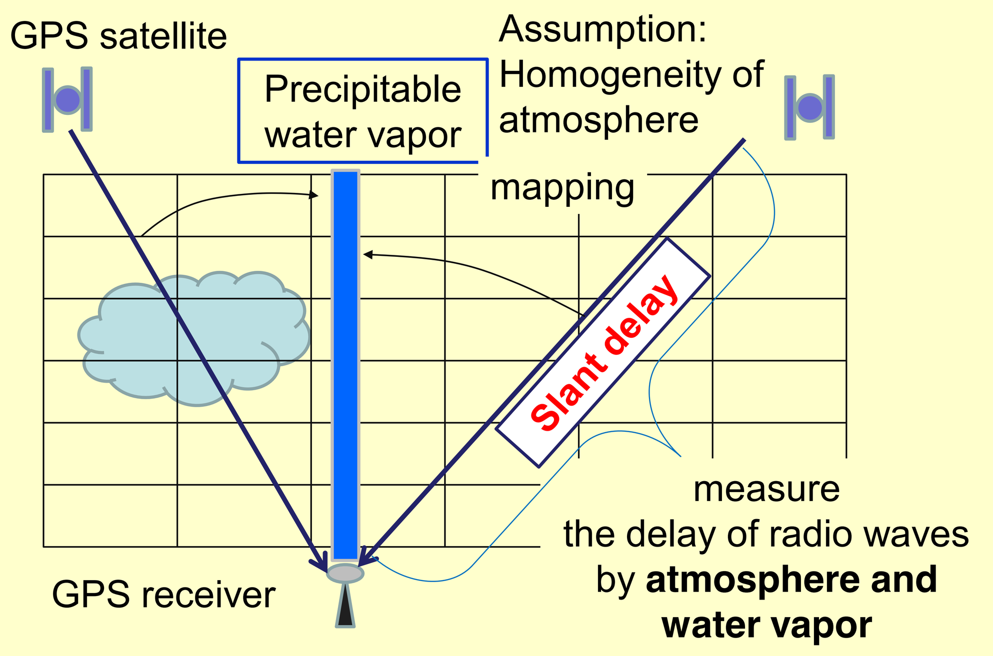
Horizontal resolution : 2 km

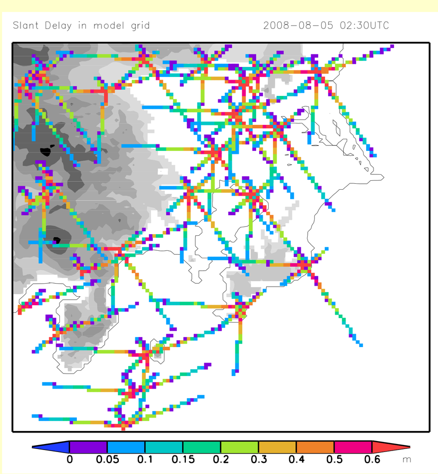
2

PWV vs SD

	GPS-PWV	GPS-SD
Water vapor	yes	yes
Pressure, temperature	no	yes
Direction	vertical	satellite
Difficulty to the assimilation	easy	difficult
Model resolution	coarse – fine	fine

What is the slant delay?




Delay on each grid boxes

How to assimilate the GPS-SD?

(a) Refractive index

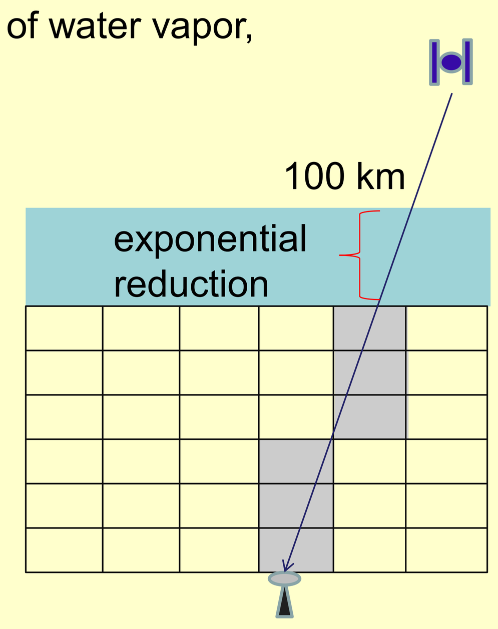
$$(n-1)\times 10^6 = \underbrace{K_1\left(\frac{P_d}{T}\right)}_{\text{Dry}} + \underbrace{K_2\left(\frac{P_v}{T}\right) + K_3\left(\frac{P_v}{T^2}\right)}_{\text{Wet}}$$

$\boldsymbol{P_d}$: Partial pressure of dry air, $\boldsymbol{P_v}$: Partial pressure of water vapor,
$\boldsymbol{T}$: Temperature, K_1, K_2, K_3: Constants

(b) Integration along the pass of radio wave.

$$\Delta L = \int_L [n(s)-1]ds + [S-G]$$

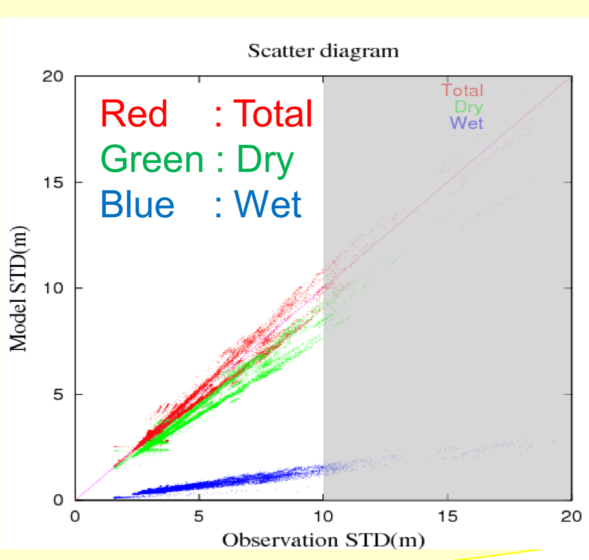
G : Distance in a straight line between the GPS satellite and the receiver.
S : Real length of propagation root of radio wave.
Assumption : S = G



(c) Assumption

- Linear path assumption (S=G)
- Amount of delay becomes ZERO at the height of 100 km over the model top with exponential reduction.

Statistics of the GPS-SD and the model



QC
Observation data are discarded if following conditions are not satisfied:

- Observation value is under 10 m
- Height difference of observation site and the model grid is less than 50 m.
- Departure value is under 1 m.

Radar and surface data are provided by Japan Meteorological Agency, GPS data by Geographycal Survey Institute.

References

- Kawabata, T., H. Seko, K. Saito, T. Kuroda, K. Tamiya, T. Tsuyuki, Y. Honda, and Y. Wakazuki, 2007: An assimilation and forecasting experiment of the Nerima heavy rainfa11 with a cloud-resolving nonhydrostatic 4-dimensional variational data assimilation system. J. Meteor. Soc. Japan, 85, 255-276.
- Kawabata, T., T. Kuroda, H. Seko, K. Saito, 2009; Radar Reflectivity Assimilation with a Cloud-Resolving Nonhydrostatic 4-Dimensional Variational Assimilation System, MWR, (submitted).
- Shoji, Y., 2009: A study of near real-time water vapor analysis using a nationwide dense GPS network of Japan. J. Meteor. Soc. Japan, 87, 455-477.

Summary

A cloud-resolving nonhydrostatic 4-dimensional variational assimilation system (NHM-4DVAR; Kawabata et al. 2009) is applied to a heavy rainfall event. Doppler radar radial winds, radar reflectivity, Global Positioning system (GPS) precipitable water vapor (GPS-PWV), surface winds and temperatures were assimilated in this assimilation experiment with 2-km grid spacing. In addition to above data, a new assimilation method on **GPS slant delay data** (GPS-SD) was developed.

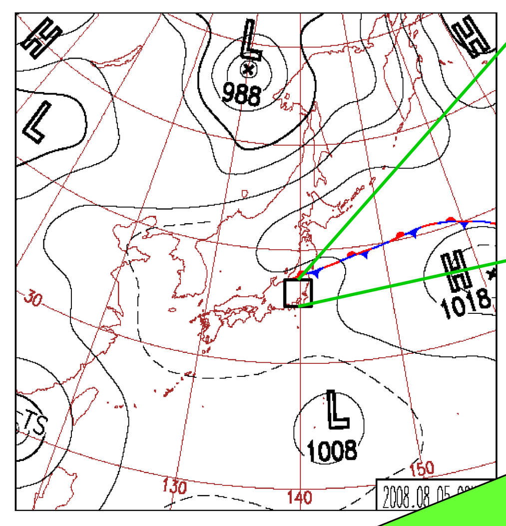
The reproduction of cumulus convection in the GPS-SD is better than one in the GPS-PWV in the assimilation window. The duration and intensity of the convection in both cases are similar, but the horizontal size in the GPS-PWV is larger than one in the GPS-SD in the forecast.

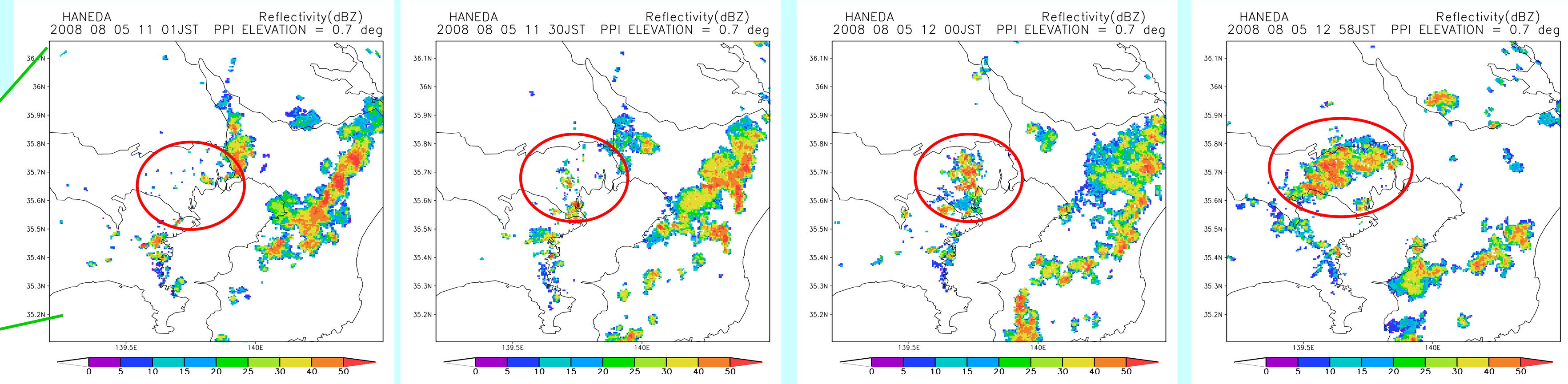
Through the horizontal distribution of water vapor, it is suggested that the small convergence of water vapor contributes to the initiation of the convection and the wider area where the amount of water vapor is large is important for the convection to develop.

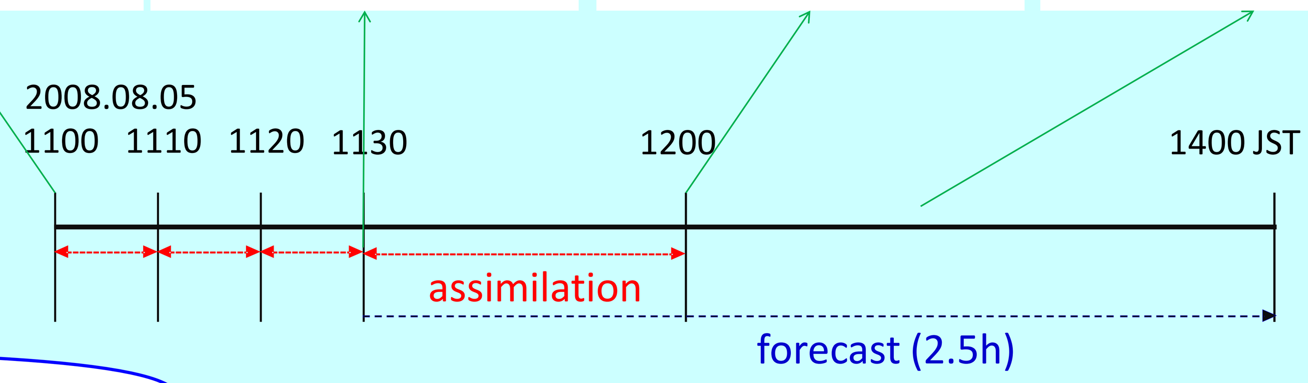
3

Assimilation experiment

Radar reflectivity observation





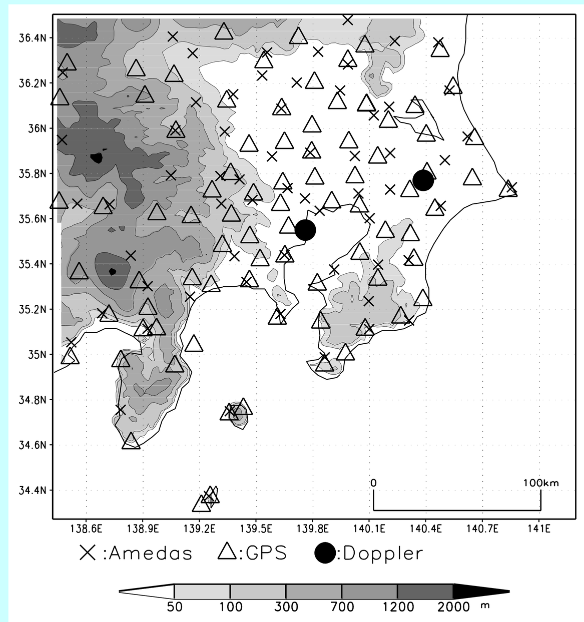


Observational Data

- Doppler radial wind (1 min)
- Radar reflectivity (1 min)
- Surface wind (10 min)
- Surface temperature (10 min)
- GPS slant delay (10 min) **GPS-SD**

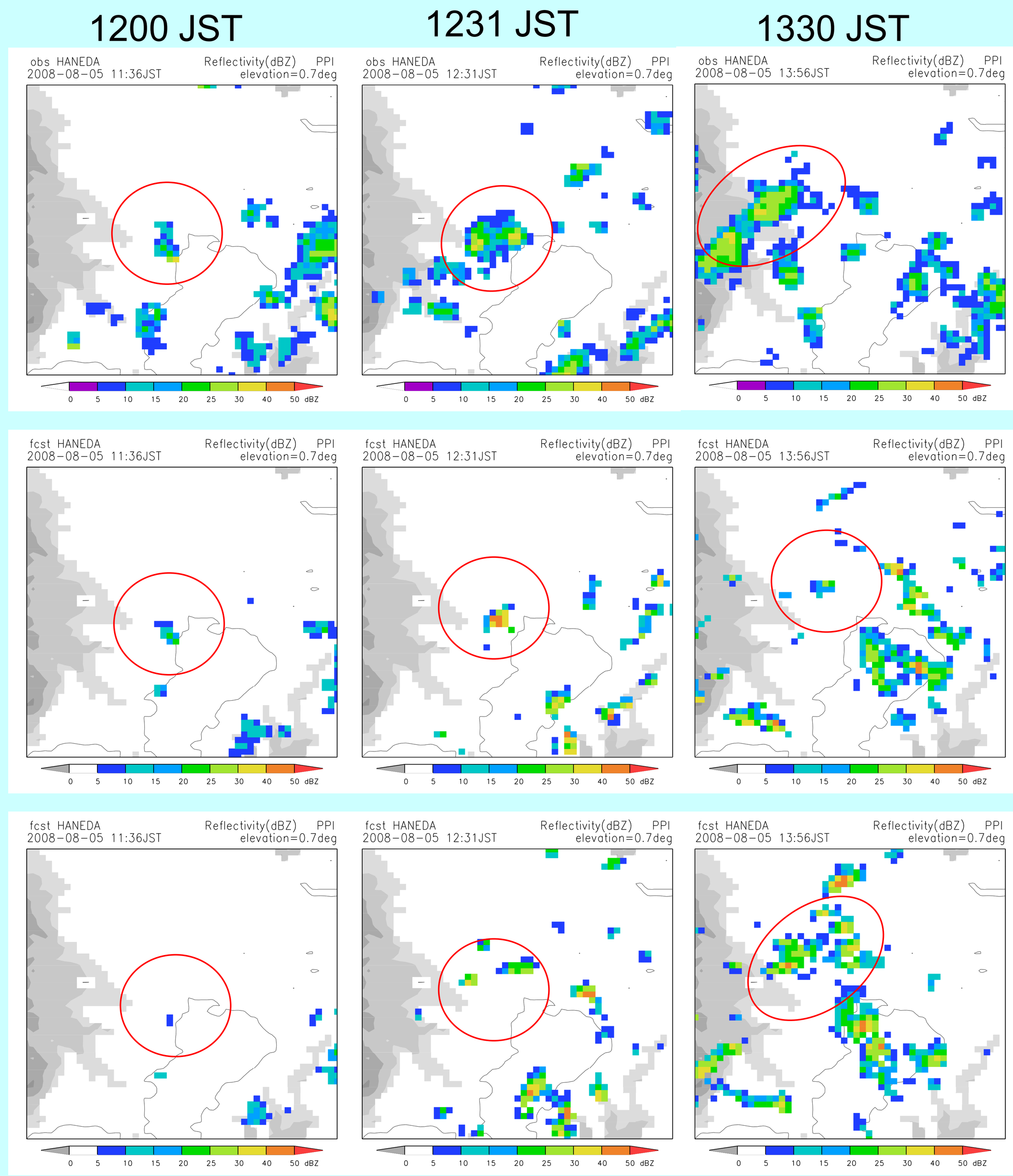
or

- GPS precipitable water vapor(10 min) **GPS-PWV**



Observation sites
assimilation area

Radar reflectivity

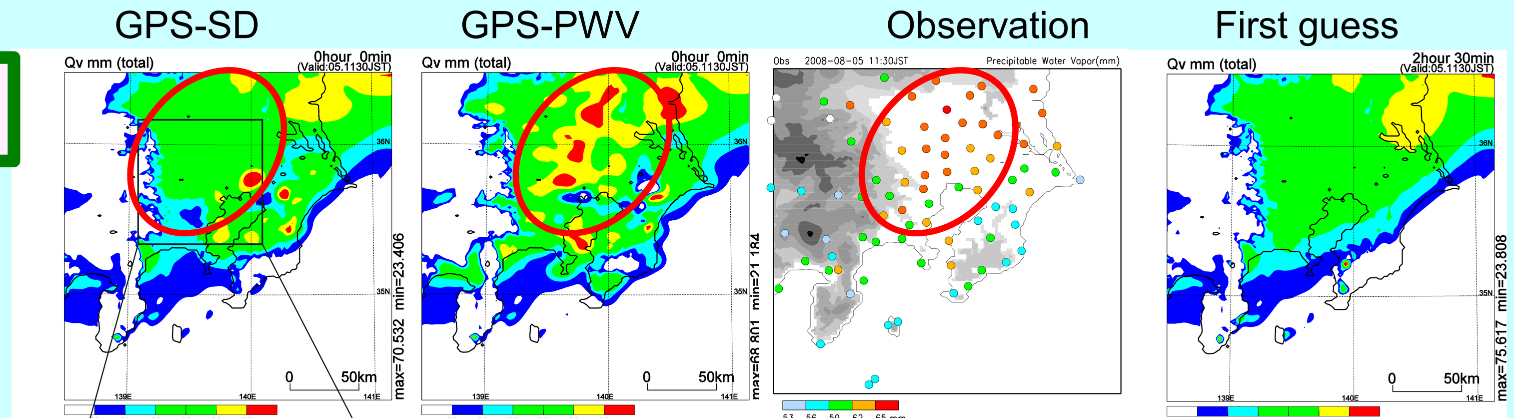


Observation: Convection initiated at 1200JST and developed at the same point until 1231 JST. After that, it developed to MCS and moved north-westerly.

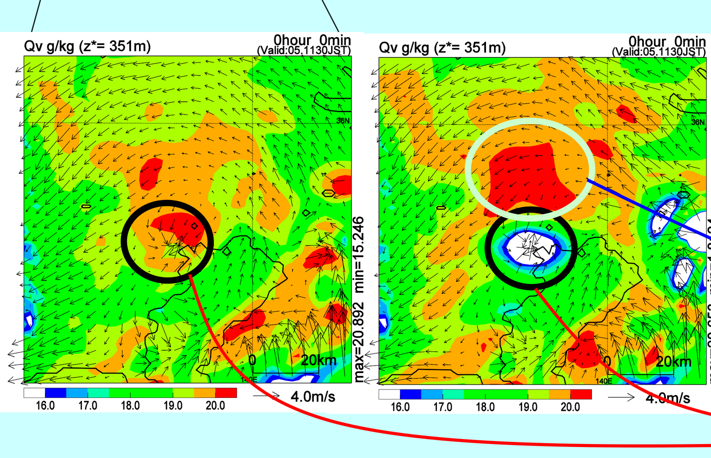
GPS-SD: Convection is reproduced at the same point of the observation and develops as the observation. The convection does not develop to MCS, but moves to northerly.

GPS-PWV: Convection is reproduced at the same point of the observation. But it is vanishes until 1231 JST, another convection is reproduced at north point. The convection develops as same as the observation.

Precipitable Water Vapor
1130 JST



Water Vapor, Wind
1130 JST
351 m

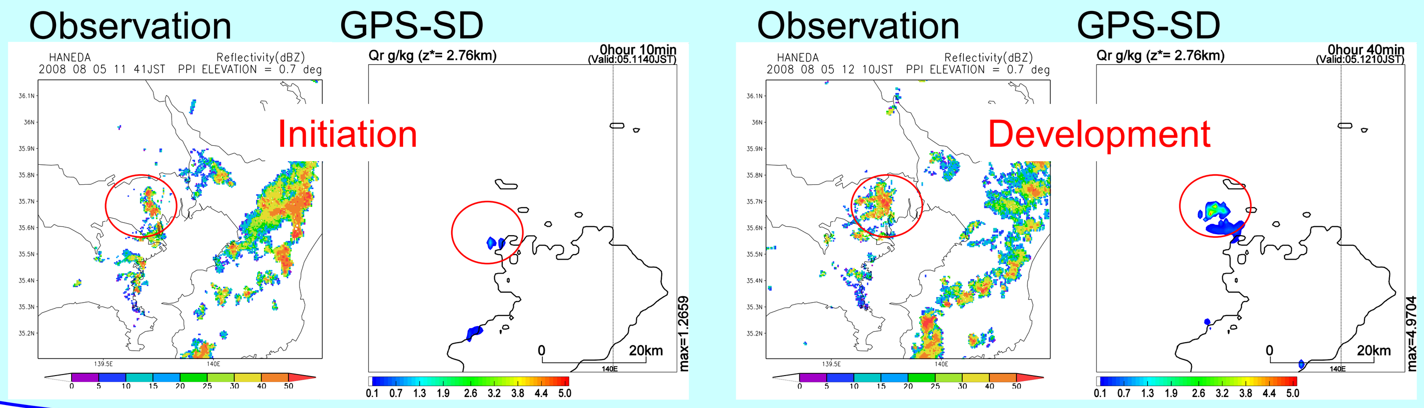


PWV on the Kanto plain by the GPS-PWV experiment is similar to observation, but the GPS-SD experiment has slightly different distribution.

Water vapor for the development

Water vapor for the initiation

Down scaling (2km -> 0.5km)



Down scaling simulation succeeds to reproduce more realistic convection than 2-km simulation..